NATIONAL ACADEMY OF SCIENCES

Number 30 • December 1959

IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation-1959 as related primarily to United States programs.

UNIVERSITY OF ILLINOIS LIBRARY DEC 2 1959 CHICAGO

Radiation Measurements in the Vicinity of the Earth and Moon

The following material is based on two reports by James A. Van Allen (one in collaboration with Louis A. Frank) of the Department of Physics and Astronomy, State University of Iowa. The reports have been published elsewhere in full: the first, "Radiation Measurements to 658,300 Kilometers with Pioneer IV," by Van Allen and Frank, appeared in Nature, *July 25, 1959; the second, "The Geomagnetically Trapped Corpuscular Radiation," appeared in the* Journal of Geophysical Research, *November 1959.*

An earlier report on radiation and magnetic-field measurements to distances of many earth radii, by US-IGY satellites and space probes, was presented in *Bulletin No. 21.* Since then, additional data gathered by US-IGY space probe Pioneer IV have been reduced and analyzed. Some data from the first USSR space probe have also become available. This report, based primarily on the analyses of Pioneer IV data, extends and amplifies some of the earlier results.

Pioneer IV

Launching and Flight: Pioneer IV was launched from Cape Canaveral, Florida, at 0511 UT on March 3, 1959. The launching was accomplished by the Army Ballistic Missile Agency and the Jet Propulsion Laboratory (JPL) of the California Institute of Technology under the management direction of the National Aeronautics and Space Administration (NASA).

The 13.4-pound, conical, gold-plated probe reached approximately its nearest approach to the moon, 60,149 kilometers (or about 37,370 miles), at 2300 UT on March 4. The probe then continued onward into a heliocentric orbit, sending back usable radiation data until 1500 UT, March 6, when its mercury batteries went dead. At this time, about 82 hours after launch, the probe had reached a point about 658,300 kilometers (or about 409,100 miles) radially from the center of the earth, a record distance for maintaining radio contact.

Objectives: The radiation experiment in Pioneer IV had the following objectives: (i) re-survey of the intensity structure of the zones of trapped radiation surrounding the earth, with special emphasis on time changes since December 6–7, 1958 (flight of Pioneer III, which reached an altitude of about 63,500 statute miles); (ii) crude determination of the absorptivity (ratio of absorbed to incident radiation) of the trapped radiation in terms of spatial position, in order to increase knowledge of its composition and spectral character; (iii) re-determination of the effective extent of the geomagnetic field; (iv) search for magnetically trapped radiation in the vicinity of the

moon; (v) re-determination of cosmic-ray intensity in interplanetary space; and (vi) search in interplanetary space for "blobs" of plasma containing particles of sufficient energy to be detected by the equipment carried.

Over-all management of the Pioneer IV program rested with NASA. The radiation experiment was directed by James A. Van Allen of the State University of Iowa (SUI), with financial support from JPL.

Instrumentation: The radiation instrumentation was identical to that flown in Pioneer III (see *Bulletins 20 and 21*) except that one of the two radiation counters used, an Anton 213 Geiger-Mueller tube, was shielded by a closed-end cylinder of lead 4.0 gm/cm^2 thick and an inner cylinder of stainless steel 0.6 gm/cm^2 thick, thus allowing discrimination of the higher-energy radiation. (See Figure 1.) The other counter, an Anton 302 Geiger-Mueller tube, was, like those used in Pioneer III, relatively unshielded. The radiation detectors and the payload assembly were developed, calibrated, and tested cooperatively by JPL and SUI.

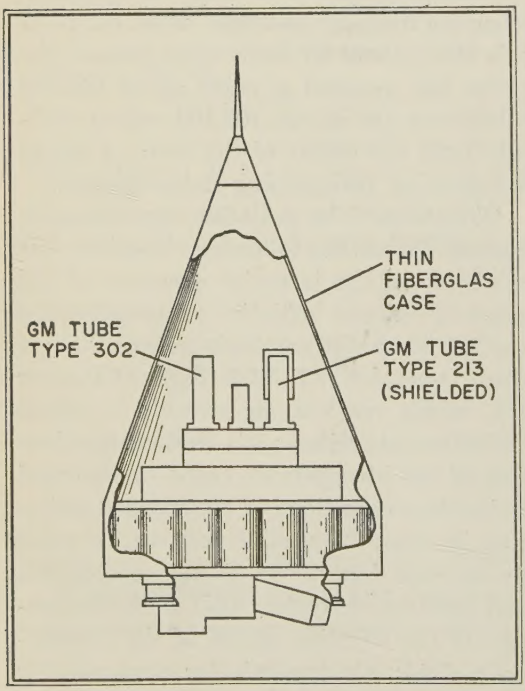

FIG. 1. *Payload of Pioneer IV.*

Radiation data were telemetered to JPL receivers at Cape Canaveral, Florida, Mayaguez, Puerto Rico, and Goldstone Lake, California. The University of Manchester's 250-foot paraboloid radio telescope at Jodrell Bank, England, under the direction of A. C. B. Lovell, also was used to track the probe.

The Geomagnetically-Trapped Radiation

After the initial discovery by US-IGY satellite Explorer I of radiation of rapidly increasing intensity above a height of about 1000 kilometers, it was concluded that this radiation must consist of charged particles trapped in the earth's magnetic field. (See *Bulletin No. 27* for a discussion of the mechanics of trapping of radiation in the magnetic field.) Subsequent measurements by additional satellites and space probes provided a wealth of evidence to support this conclusion, which may now be regarded as established beyond doubt. The following discussion in this section concerns the intensity structure, character, variations, origins, and geophysical effects of this geomagnetically trapped radiation.

Intensity: In Figure 2, the counting rates of the nearly identical Anton 302 tubes of both Pioneer III and Pioneer IV are plotted against radial distance from the center of the earth. Also shown is the equivalent counting rate of the heavily shielded 213 tube for the first part of the Pioneer IV flight. Figure 3 shows the paths of both probes through the Van Allen radiation zones.

The most striking features evident in Figure 2 are (i) the immensely greater quantity of radiation trapped in the outer radiation zone on March 3, 1959, (over 300,000 counts/sec), than on December 6, 1958, (about 25,000 counts/sec); (ii) the considerable outward extension of the outer

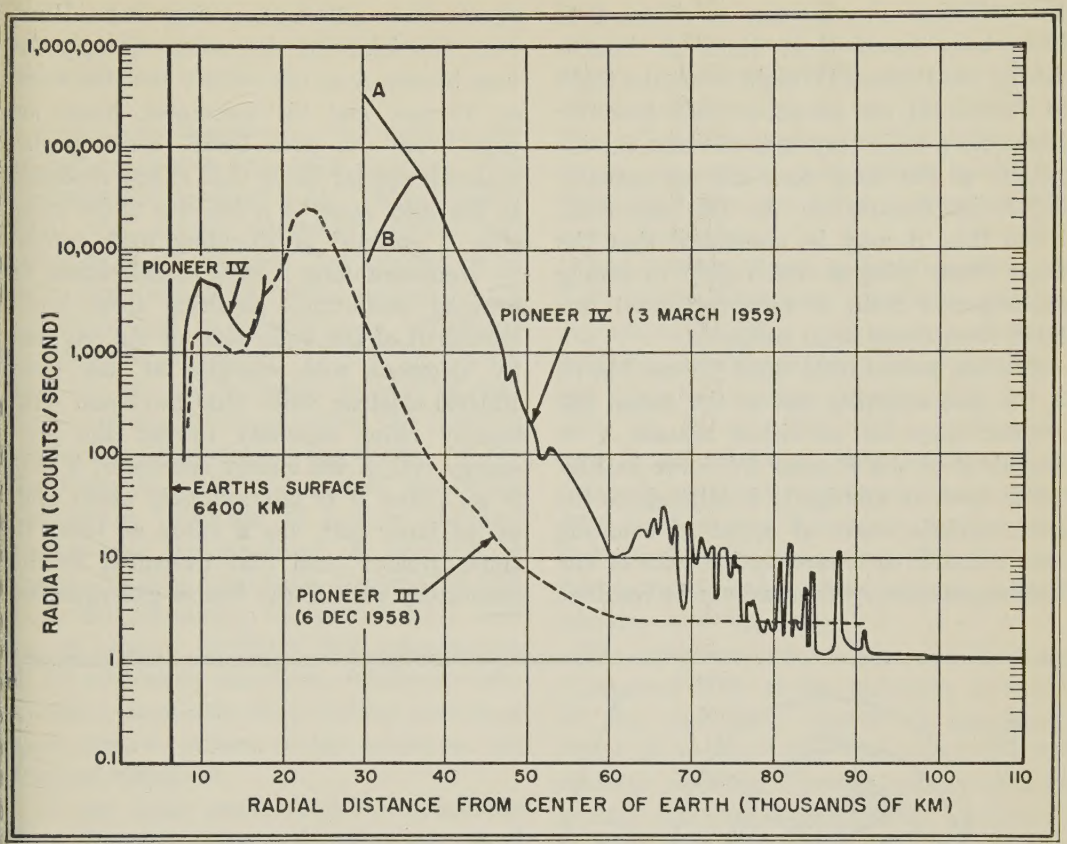

FIG. 2. *Comparative Plots of Intensity Data from Pioneer III and Pioneer IV. Same scale is used for both plots but differences in latitude and longitude are ignored.*

zone (about 15,000 kilometers); and (iii) the detailed intensity structure present in the March 3 record, especially in the 60,000–90,000 kilometer region.

S. N. Vernov and his associates report that observations with the first Soviet space probe show that the radiation pattern on January 2, 1959, was similar to that on December 6–7, 1958.

The High Altitude Observatory, at Boulder, Colorado, reports that a substantial geomagnetic storm began at 0215 UT, February 25, 1959, and that intense auroras occurred on February 25, 26, 27, and 28 and on March 1. A special study by D. E. Trotter of HAO indicates that at least three sequences of geophysical events starting on February 25, March 26, and April 23, 1959, may have been caused by a solar M-region. (An M-region is an active region of the sun emitting a continuous, limited beam of solar corpuscles, causing geomagnetic storms to recur at about 27-day intervals in accordance with the sun's rotation.)

The periods preceding the flights of Pioneer III and the first Soviet space probe, on the other hand, were especially quiet geophysically. Hence, the SUI investigators suggest that the great intensity differences shown in Figure 1 between the flights of December 6, 1958, and March 3, 1959, constitute a direct observation of changes in the outer zone of trapped radiation following strong corpuscular emission from the sun. Thus, if this view is accepted, it appears that the Pioneer IV observations are the most persuasive direct evidence thus far available in support of the solar origin of at least the outer radiation zone.

Although the peak of the inner Van Al-

len radiation zone appears in Figure 2 to have been about three times as intense during the Pioneer IV flight as on the flight of Pioneer III, certain adjustments based on the probe's trajectory indicate that the intensity of the inner zone did not actually differ significantly on the two occasions. From this, it may be concluded that the inner zone, lying in the region of strong geomagnetic field, is relatively well isolated from *direct* solar influence.

For the period 0631–0653 UT on March 3, the true counting rate of the Anton 302 counter may lie on either branch A or branch B of the Pioneer IV curve in Figure 2. Such an ambiguity is intrinsic to the characteristic curve of apparent counting rate relative to true counting rate of the instrumentation system and can be resolved conclusively only by auxiliary data. However, the following discussion strongly favors branch A as the correct one: the work of Vernov. and his associates, based on data from the first USSR space probe, makes it appear likely that effects recorded in the outer zone by a detector under more than 1 gm/cm^2 of shielding were caused by bremsstrahlung X-rays (deceleration, or braking, radiation) resulting from bombardment of the outer skin of the payload by electrons with energies of less than 100,000 electron volts (100 kev) and with steeply rising intensity toward the low-energy end of the energy spectrum; if this is so, curve B is unreasonably steep and, at its inner end, has a value at least 10 times greater than that measured in the laboratory with X-ray beams generated by

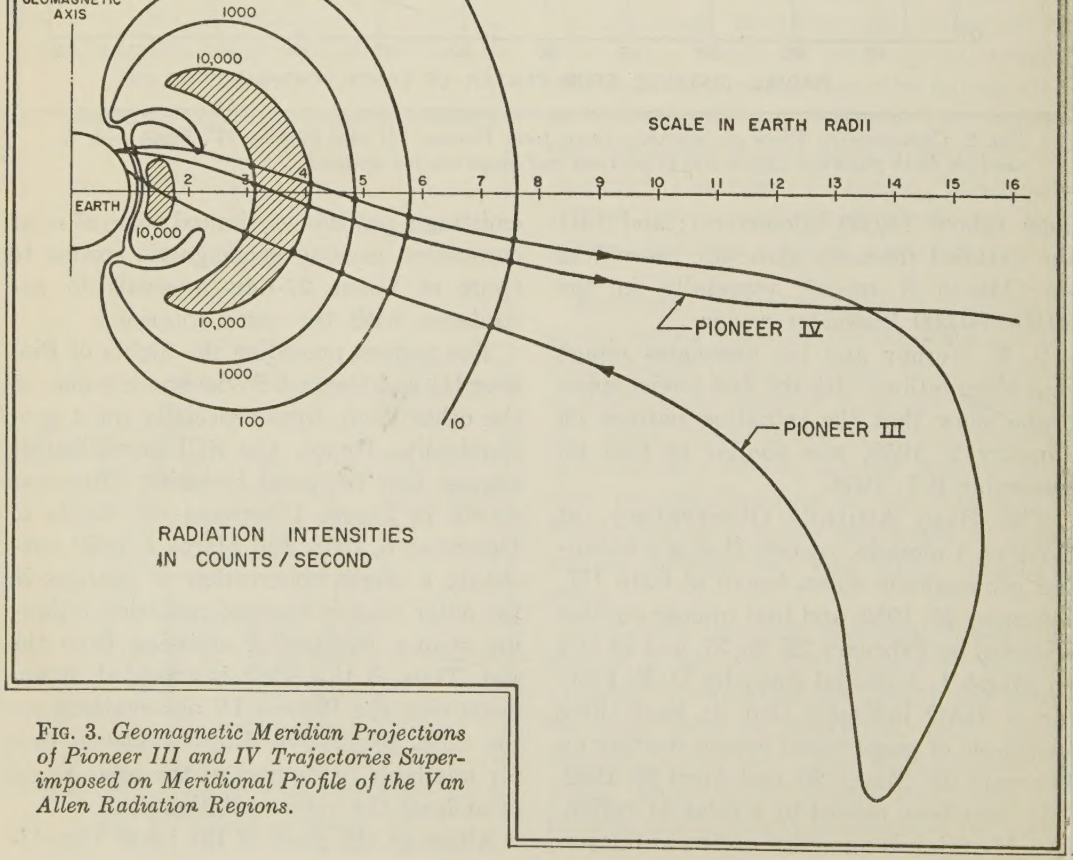

FIG. 3. *Geomagnetic Meridian Projections of Pioneer III and IV Trajectories Superimposed on Meridional Profile of the Van Allen Radiation Regions.*

electrons of similar energies; curve A, on the other hand, is altogether consistent with this radiation situation.

Character: Because of their universality in nature, it was originally supposed that electrons were present in the trapped radiation. Also, among the many nuclear possibilities, it was thought that protons (H^+) were most likely dominant because of the preponderance of hydrogen as an atomic constituent of matter. If the hypothesis that the trapped radiation consists of electrons and protons is accepted, the problem of further determining the nature of the radiation then becomes one of measuring the energy spectrum of each of the two components as functions of position in space, direction, and time. Despite the fact that the measuring equipment used thus far in rockets, satellites, and space probes is, by laboratory standards, relatively rudimentary, available observations provide a good general picture of the nature of the trapped radiation.

It has been demonstrated conclusively that the composition and energy spectra of the components of the trapped radiation in the inner Van Allen zone are quite different from those of the radiation trapped in the outer zone; the difference from one zone to the other is much greater than that between various parts of a particular zone.

The intensity of the radiation in the inner zone decreases by a factor of 10 between ranges of 1 mg/cm^2 and about 140 mg/cm^2. It falls off more gradually at ranges above 140 mg/cm^2. (Range refers to the penetrating power of a particle—i.e., the particle would penetrate any material to a thickness at which a cm^2 column would have the weight indicated.) Of the radiation that penetrates 140 mg/cm^2, a fraction of 1% also penetrates several gm/cm^2. This more penetrating component is tentatively identified as protons with energies of the order of 100 million electron volts (mev). The less penetrating component has a low specific ionization and, therefore, probably consists of electrons with energies up to about 1 mev and having an energy spectrum rising steeply toward lower energies (though not as steeply as that of auroral soft radiation—the relatively low-energy corpuscular radiation originating in solar flares and thought to cause the aurora).

Total energy fluxes as high as 100 ergs/cm^2/sec/ster have been recorded beneath 1 mg/cm^2 of shielding at an altitude of about 2000 kilometers near the geomagnetic equator. (One erg equals approximately 6.3×10^{11} ev; a steradian is a unit solid angle.) As measured with a thin (0.92 gm/cm^2) cesium-iodide crystal, more than 95% of this energy flux was in the less penetrating electron component. (Total energy flux is the product of individual particle energies and intensity.)

The observations of Pioneer IV show that about 30% of the radiation recorded by the unshielded counter in the lower fringe of the inner zone also penetrates the shielded counter. The radiation becomes rapidly and progressively softer (less penetrating) with distance from the earth, and in the outer zone it is almost completely absorbed by the 4 gm/cm^2 of lead shielding the Anton 213 counter.

On the basis of recent rocket studies of the lower fringe of the inner zone, by F. E. Holly and R. G. Johnson and by S. C. Freden and R. S. White, and of the extensive Explorer IV, Pioneer III, and Pioneer IV observations, the following tentative composition of the radiation trapped in the heart of the inner zone (at an altitude of about 3600 kilometers above the geomagnetic equator) is proposed by the SUI investigators: (i) electrons of energy greater than 40 kev having a maximum unidirectional intensity of about 2×10^9/cm^2/sec/ster; (ii) electrons of energy greater than 600 kev having a maximum unidirectional intensity of about 1×10^7/cm^2/sec/ster; and (iii) protons of energy greater than 40 mev having an omnidirectional intensity of about

$2 \times 10^4/cm^2/sec$. (The last two figures are probably reliable within a factor of two, the first within a factor of five.)

All evidence thus far is consistent with a composition almost exclusively of electrons for the outer zone. The energy spectrum apparently resembles that of auroral soft radiation—rising steeply toward low energies from an approximate upper limit of about 100 kev. On the basis of the simplest (though not conclusively the only) possible interpretation, in the heart of the outer zone (30,000 kilometers radial distance), the omnidirectional flux of electrons with energies greater than 40 kev is about $10^{11}/cm^2/sec$; also, the omnidirectional intensity of electrons of energy greater than 200 kev is less than $10^8/cm^2/sec$, of electrons with energies greater than 2.5 mev, less than $10^6/cm^2/sec$, and of protons of energies greater than 60 mev, not more than $10^2/cm^2/sec$.

From its behavior during the period of observation, it is inferred that the inner zone remains relatively stable with time. However, there are marked temporal fluctuations in the "slot" between the two zones, and there are fluctuations of very great magnitude, with respect to both intensity and spatial structure, in the outer zone, particularly in the "horns" where the zone approaches closest to the earth's surface.

Origin: There is little doubt that the great outer zone of geomagnetically trapped radiation, and the rich variety of associated geophysical effects, are directly attributable to solar gas injected into and temporarily trapped in the the geomagnetic field.

The site and the mechanism of acceleration of the solar gas particles to observed energies are major problems still unsettled. Two possible solutions are: (i) acceleration within the sun by betatron-type or other mechanisms and "piping" to the earth's vicinity along extended magnetic lines of force, and (ii) intrusion into the earth's magnetic field of low-energy particles (about 10^4 ev) from a cloud of solar gas, trapping, and subsequent acceleration by magnetohydrodynamic waves or by other processes in the local earth environment. Further studies in interplanetary space, involving radiation monitoring over an extended period of time, are needed to resolve this problem.

Various workers have proposed origins other than solar, at least in part, for the radiation trapped in the Van Allen zones. H. V. Neher has suggested that a penetrating component may arise from the delayed radioactive decay of mu-mesons emerging from the earth's atmosphere as part of the cosmic-ray albedo (the secondary cosmic radiation emerging outward from the atmosphere). N. C. Christofilos, S. N. Vernov, P. J. Kellogg, and S. F. Singer, separately, have postulated the neutron component of the cosmic-ray albedo as a possible source, and Singer has emphasized the potential of such high-energy neutrons for generating the penetrating component of the inner zone. These suggestions all depend on the ability of neutrons produced by nuclear disintegrations induced by cosmic-ray bombardment of the atmosphere to move outward through the geomagnetic field, undeflected by the field or by collisions with other particles, until they undergo radioactive decay.

The observed energy spectrum and composition of the inner-zone radiation resemble those to be expected in the neutron-decay hypothesis of origin. The electrons making up the major component have an energy spectrum resembling that of neutron-decay electrons. The minor (but more penetrating) component, consisting of protons with energies of the order of 100 mev, may possibly represent part of the decay products of a few tenths of 1% of the fast neutrons making up a portion of the neutron albedo.

Many quantitative factors, such as source strength, trapped lifetimes, equilibrium spectra, etc., must be examined more fully

before the neutron-decay theory of origin of the inner zone can be established with certainty. Although present knowledge, particularly that based on the recent work of W. N. Hess, favors the neutron-decay theory, some workers feel that the source strength of the mechanism may be inadequate. T. Gold has suggested that the inner zone may contain an important admixture of particles that have been "convected" inward from the outer zone.

A number of workers have also noted the sporadic, but relatively frequent (averaging about once a month), arrival of solar protons with energies up to several hundred mev and intensities up to several orders of magnitude greater than that of the quiet cosmic-ray beam. Some investigators, including those at SUI, find it difficult to accept the trapping lifetime of several years required by the neutron-albedo hypothesis. Hence, this alternative source of protons (i.e., solar emission) of suitable energy and intensity provides another possible solution—if a valid mechanism for their admission into the inner zone can be found. Observations made during the coming period of minimum solar activity may provide illuminating evidence on temporal changes in both radiation zones.

Geophysical Role: On the basis of particle energies and intensities, geometric form of the trapped-radiation zones, estimated leakage rates into the earth's atmosphere, and general considerations of plasma physics, it appears quite plausible that the trapped radiation acts as an intermediate reservoir of charged particles between the sun, as source, and the earth's atmosphere. Resulting geophysical phenomena include the aurora, airglow, possible atmospheric heating, geomagnetic storms, etc. In addition, the trapped radiation may be the seat of the electrical current ("ring current") long supposed to be responsible for the main phase of geomagnetic storms.

Soviet reports of measurements with the USSR space probe on January 2, 1959, indicate a gradual and progressive fall in magnetic-field strength (relative to the field extrapolated from surface measurements) between radial distances of 14,000 and 21,000 kilometers, and a subsequent rise approximately back to the theoretical value at 26,000 kilometers and beyond. These findings imply the existence of a westward-flowing ring current with an apparent maximum current density at a radial distance of about 21,000 kilometers from the earth's center. The most intense part of the ring current appears to lie along the inner side of the region of peak radiation intensity of the outer zone, where the gradient of the volume density of charged-particle kinetic energy is, in fact, at its greatest value. Further determination of the relationship between this ring current and the trapped radiation now becomes a most challenging problem for geophysicists.

It may be speculated that modification of the geomagnetic field by the ring current at a distance of about three earth radii influences the structure of the radiation zones and perhaps contributes to the existence of the slot between the two zones.

Intensity Beyond 92,000 Kilometers

The unshielded Geiger-Mueller tube in Pioneer IV provided a total of 45 hours of counting-rate observations between 92,000 and 658,300 kilometers from the center of the earth. (The shielded tube was not sufficiently sensitive to provide data during this portion of the flight.) The counting rate during observed periods (695 four-minute intervals) at no time differed with statistical significance from the over-all mean value of 1.090 ± 0.003 counts per second. The constancy of the counting rate during these periods encouraged the investigators also to "count through" the unobserved periods (during which the probe was below the effective horizons of the receiving stations) on the assumption that the counting rate for the unobserved intervals did not differ markedly from that during periods

of observation. It was found that the unobserved counting rates differed by less than 1% from the adjacent observed ones.

Solar Plasma in Interplanetary Space

On the basis of the counting-rate data, it appears that Pioneer IV did not encounter any solar plasma containing particles of sufficient energy to register on the unshielded counter during the 76-hour interplanetary portion of the Pioneer IV flight, March 3–6, 1959. This absence of energetic solar plasma is particularly notable since one theory of origin of the earth's outer radiation zone requires sporadic solar ejection of such plasma. The paucity of energetic plasma is also especially striking in view of the strong geophysical activity recorded during the previous week. The alternative theory of origin, that acceleration of the components of the plasma to high energies occurs in the geomagnetic field, is therefore implied.

Based on the characteristics of the observing equipment, it is concluded that during this 76-hour period, the time-integrated flux of higher-energy electrons and protons could not have exceeded 100/cm² in an isolated burst during any one of the 695 intervals of observation; nor could it have exceeded 1000/cm² in an isolated burst during any one of the three unobserved periods having a duration of some 10 hours each, or exceeded 2×10^5/cm² if distributed uniformly (an unlikely condition) throughout the 76-hour period. By comparison, the corresponding values for lower-energy electrons (60 kev and less) would be 4×10^5 times as great.

Interplanetary Cosmic-Ray Intensity

From the counting-rate of the Anton 302 tube in Pioneer IV, a value of 1.8 ± 0.3/cm²/sec is obtained for the interplanetary omnidirectional cosmic-ray intensity (J_0) during the period March 3–6, 1959. This value is ½ that obtained for December 6–7, 1958, from Pioneer III measurements. However, on the basis of a recent re-study of the data, C. W. Snyder presents evidence that Pioneer III did not reach a great enough distance to be entirely free of the influence of the earth's magnetic field.

Since the Pioneer IV observations to very much greater distances are not subject to this uncertainty, considerably greater confidence can be attached to the new value (though it should be understood that the counter was capable of also recording low-energy protons and electrons). In any case, the Pioneer IV value provides a solid upper limit for total primary cosmic-ray intensity in the general astronomical vicinity of the earth during early March 1959.

Using balloon-borne equipment, F. B. McDonald found the following intensities of primary unidirectional cosmic-ray components (corrected to zero atmospheric depth, or to regions beyond the influence of the earth's atmosphere) at geomagnetic latitude 55° N on July 2, 1958: protons of energy greater than 280 mev, 0.0950 ± 0.0070/cm²/sec/ster; alpha particles of energy greater than 158 mev/nucleon (or 632 mev/particle), 0.0149 ± 0.0012. An interesting comparison results from multiplying the sum of these values, 0.11/cm²/sec/ster, by 4π to obtain an estimate of J_0. The result is: $J_0 = 1.38$/cm²/sec. Insofar as McDonald has been able to eliminate fast, downward-moving albedo from his data, this value has the nature of a lower limit to the total primary cosmic-ray intensity for the period of measurement. Vernov and his associates report a value of 2.3 ± 0.1/cm²/sec for J_0 on January 2, 1959.

Effective Extent of the Geomagnetic Field

The earlier interpretation of Pioneer III observations *(Bulletin No. 21)* produced the conclusion that the earth's magnetic field loses its ability to trap charged particles at a distance of about 10 earth radii.

Snyder's calculations (above) now make this value appear too small. The Pioneer IV observations, as shown in Figure 2, indicate that geomagnetic trapping is significant to a distance of about 14 earth radii, at least on specific occasions. The loss of trapping efficiency is a loosely defined concept, and marked fluctuations undoubtedly occur in the radiation regions at the outer fringes of the geomagnetic field.

Trapped Radiation Around Other Planets and the Moon

The magnetic trapping of charged particles in the vicinity of astronomical bodies is undoubtedly a quite general astrophysical phenomenon. The outward movement of cosmic-ray-produced neutrons from the atmospheres or solid surfaces of astronomical bodies is also probably a universal phenomenon—at least within our galaxy. In addition, all bodies of the solar system are subject to bombardment by solar plasma, with greater or lesser intensity depending on their distances from the sun. Hence, both of the presumably most important sources of trapped radiation are present throughout our solar system.

The principal elements in a general, quantitative study of trapping are the magnetic moment and radius of the body, and the density and radial extent of its atmosphere. The trapping mechanism is now sufficiently well understood that a reasonably confident assessment can be made for any known set of these elements. In general, the greater the magnetic moment and the less extended the atmosphere, the more favorable are the conditions for a high intensity of trapped radiation.

Pioneer IV, which obtained observations as close as 61,700 kilometers to the moon, recorded no significant change in counting rate in the vicinity of the moon. It therefore appears likely that the moon is surrounded by little or no trapped radiation.

Mars and Venus, however, the planets nearest and hence of most immediate interest to us, may well be surrounded by substantial belts of trapped radiation.

International Geophysics Committee and International Geophysical Cooperation in 1960 and 1961

The following material is condensed from a more complete report, "International Geophysics Committee," by Hugh Odishaw (Director, World Data Center A, National Academy of Sciences), published in the Transactions of the American Geophysical Union, *Volume 40, Number 4, December 1959, pages 347–350.*

The International Geophysics Committee (Comité Internationale de Géophysique, or CIG) held its first and organizing session at The Hague, November 4-6, 1959. CIG was established by the International Council of Scientific Unions (ICSU), the parent body of IGY, in conjunction with four of its member unions: the International Union of Geodesy and Geophysics (IUGG), the International Astronomical Union (IAU), the International Scientific Radio Union (URSI), and the International Union of Pure and Applied Physics (IUPAP).

The CIG's purpose is twofold: (i) to ensure the fullest possible exploitation of

the data accumulated during IGY and IGC-59 (see *Bulletin No. 28* for further information on the IGC-59 program) by maintaining the efficient functioning of the World Data Centers established as part of the IGY, encouraging discussion and use of IGY and IGC-59 results, and publishing these results and bibliographies; (ii) to develop and coordinate international plans for further cooperation in geophysics and related sciences, especially those of an interdisciplinary nature, by assembly and intercomparison of national programs, arranging for international data interchange and continued use of the WDC's, and encouraging discussion and publication of the results of such programs.

The presidents of ICSU, IUGG, IAU, URSI, and IUPAP established the membership of CIG as follows:

Bureau members: President, V. V. Belousov (USSR); three Vice Presidents, Edward Appleton (UK), John R. Winckler (USA), and M. Minnaert (Netherlands); Secretary, G. Laclavere (France).

Other members: meteorology, J. van Mieghem (Belgium); nuclear radiation, B. Bolin (Sweden); aeronomy, M. Nicolet (Belgium); geomagnetism, V. Laursen (Denmark); aurora and airglow, C. T. Elvey (USA); solar activity, M. A. Ellison (Ireland); ionosphere, W. J. G. Beynon (UK); cosmic rays, S. N. Vernov (USSR); oceanography, V. G. Kort (USSR); glaciology, G. de Q. Robin (Australia); seismology, F. Press (USA); and paleogeophysics, T. Nagata (Japan). In accordance with the CIG charter, representatives of World Data Centers A and B, Hugh Odishaw (USA) and P. K. Evseev (USSR), became members upon designation by their academies.

CIG's first meeting was concerned with the charter of the committee's functions, composition, and procedures, as drafted by the ICSU Executive Board; with completion of IGY and IGC-59 endeavors; and with international cooperation in geophysics and related sciences in the future.

Completion of IGY and IGC-59 Efforts

CIG considered completion of the IGY and IGC-59 efforts to be its first and most urgent task, and publication of the *IGY Annals* was deemed the most important aspect of this task. The CSAGI Reporters, who have in effect been serving as a board of editors for the *Annals*, each responsible for his particular discipline, were chosen to continue in this capacity in accordance with prior IGY resolutions. Their task is to compile, prepare for publication, and edit IGY-IGC results, largely embracing (i) the various types of processed data and (ii) summary reports.

In addition, the CIG urged participating IGY committees to complete IGY data interchange and to expedite IGC data flow, authorizing the Secretary to monitor this activity. The CIG also requested that the WDC's continue to prepare, issue, and distribute the cumulative six-month catalogues through December 31, 1960. The Secretary was asked to review this activity and to prepare and distribute cumulative six-month catalogues embracing all disciplines. Provisions were also made for publication of these catalogues in the *Annals*.

Plans and Recommendations

Although much analysis and interpretation of IGY and IGC observations has already been accomplished, the unprecedented extent of this body of data represents an immediate and compelling challenge to geophysics. Hence, CIG called upon adhering scientific institutions to encourage and intensify much-needed and highly valuable analytical and theoretical studies during the next two years. So significant was this activity deemed that the committee formally characterized the two-year interval, January 1, 1960—December 31, 1961, as "the IGY-IGC analysis and theoretical research period." It was stressed that research papers should be published in the customary scientific journals.

International Geophysical Calendar 1960

Issued October 1959 by the International World Day Service under the auspices of the International Council of Scientific Unions

1960 JANUARY 1960

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	(12)	(13)	(14)	15	16 *
* 17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

1960 FEBRUARY 1960

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	(16)	(17)	(18)	19	20
21	22	23	24	25	26	27
28	29					

1960 MARCH 1960

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	(15)	(16)	(17)	18	19
20	21	22	23	24	25	26
[27]	28	29	30	31		

1960 APRIL 1960

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	(19)	(20)	(21)	22	23
24	25	26	27	28	29	30

1960 MAY 1960

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	(17)	(18)	(19)	20	21
22	23	24	25	26	27	28
29	30	31				

1960 JUNE 1960

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	(14)	(15)	(16)	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

1960 JULY 1960

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	(12)	(13)	(14)	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

1960 AUGUST 1960

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	(9)	(10)	(11)	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

1960 SEPTEMBER 1960

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17 **
** 18	19	(20)	(21)	(22)	23	24
25	26	27	28	29	30	

1960 OCTOBER 1960

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	(18)	(19)	(20)	21	22
23	24	25	26	27	28	29
30	31					

1960 NOVEMBER 1960

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	(15)	(16)	(17)	18	19
20	21	22	23	24	25	26
27	28	29	30			

1960 DECEMBER 1960

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	(13)	(14)	(15)	16	17
[18]	19	20	21	22	23	24
25	26	27	28	29	30	31

1961 JANUARY 1961

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	(17)	(18)	(19)	20	21
22	23	24	25	26	27	28
29	30	31				

(12) Regular World Day

(18) Regular World Day with highest priority

21 Day with unusual meteoric activity

[27] Day of solar eclipse

		17	18	19	20	21
22	23	24	25	26		

Regular World Interval (RWI) combined with World Meteorological Interval (WMI)

Notes * January 11 to 20 is WMI only.

** September 16 to 22 is Provisional International Rocket Week, dates to be confirmed by COSPAR

FIG. 4. *Calendar of World Days for 1960.*

CIG also considered the problem of which activities, if any, merited conduct under an international aegis. The activities of IGC-59 were cited as models. These observational programs represented at most an effort only slightly greater than that which the various participating countries would have undertaken in any event. Yet, as formalized in a simple manner under IGC-59, they permitted continuity of international discourse in geophysics and, above all, sustained interchange of data through an existing mechanism. CIG therefore called for a similar effort during 1960 and 1961, to be effected by two actions of adhering scientific bodies: first, submission of program documents, which would serve to inform all participants of the nature and scope of national contributions and, second, an interchange of observational data through the WDC's.

Both IGY and IGC-59 called for extensive interchange of data, particularly in the synoptic areas—meteorology, ionospheric physics, aurora, airglow, geomagnetism, and solar activity. Although essentially complete bodies of such data were accumulated during the 1957-59 period, and their exchange was relatively thorough, it does not necessarily follow that requirements will be identical in the years ahead. Accordingly, CIG recommended periodic critical review of this matter. More specifically, the discipline members of the committee and the CSAGI Reporters were asked to examine "the needs and interests of science with respect to future interchange in consultation with relevant Union organizations and to recommend to the CIG, discipline by discipline, the exact nature and form of future [post-1959] data interchange."

Uninterrupted operation of the World Data Centers was deemed necessary, however, partly because they afford a natural, existing data-collection medium and partly because they already represent an invaluable depository for the research worker. Many decades will pass before these rich reservoirs are exhausted, providing as they do a unique opportunity to correlate data in many fields. Special note was taken of US and USSR intentions to continue their centers and of Japanese plans to extend theirs to embrace all upper-atmosphere disciplines.

In addition to providing a basis for international continuity in "normal" geophysical studies, as suggested above, CIG considered special endeavors that might be undertaken. In this connection, special notice was taken of the World Magnetic Survey planned for a quiet interval in the solar cycle. This survey was initially proposed early in the IGY by Professor Sydney Chapman, and has recently been under intensive study, particularly by the IUGG International Association of Geomagnetism and Astronomy. CIG not only endorsed the Survey but suggested that "adjoint programmes in the fields of upper atmosphere research should be considered" for this same period, a few years hence. CIG concluded its consideration of the broad subject of future special efforts with an invitation for assistance from its discipline members, the sponsoring unions, and adhering academies.

The proposed two-year observational period of 1960-61, the ensuing pattern of data interchange, the World Magnetic Survey and, possibly, related studies during sunspot minimum, and proposals for additional major researches in years ahead will all be discussed at one time or another during the next year or two. The General Assemblies of IUGG and URSI, and associated international symposia, afford splendid opportunities for colloquies among specialists. However, some of these topics require prompt consideration, since planning and organizing of even the simplest type, whether nationally or internationally, takes time. Hence, CIG will meet again in late March or early April of 1960, and a meeting of the World Data Centers and of the Permanent Services is tentatively scheduled for May 1960. National programs for

1960-61 may well be called for and arrangements for data interchange outlined.

Organization of Programs

Just as IGY's scientific strength rested heavily upon the CSAGI Reporters, the programmatic responsibilities of CIG fall largely upon the discipline members. It is expected that the Unions will provide support through their specialized groups, thus broadening the base of the discipline members' suggestions and recommendations. Close relationships between CIG and special committees are also necessary. In particular, provisions are included for appropriate liaison with the following three ICSU committees: COSPAR, which has cognizance over rocket and space science; SCAR, which is responsible for Antarctic activities; and SCOR, which is concerned with all aspects of oceanic and marine sciences. Similar ties exist with the International World Days Service, which will continue the World Days program that proved so valuable during IGY and IGC-59. (See Figure 4.)

National participation in CIG activities is recognized as a responsibility of the scientific organizations adhering to ICSU. In the United States, the National Academy of Sciences must accordingly determine the appropriate mechanism for its cooperation with CIG. Discussions during the last year suggest that the variety of interests in the United States calls for an approach that combines the interests and competences of the four US National Committees serving as domestic counterparts to IUGG, IAU, URSI, and IUPAP, together perhaps with representation of several specialized Academy committees. The Executive Committee of the American Geophysical Union, at its meeting on November 14, 1959, endorsed in principle an approach of the above kind and indicated its intent to participate vigorously in the actions of such a body.

Ice Thickness and Bottom Topography of the Filchner Ice Shelf and Along the Ellsworth-Byrd Traverse Route

The following material is based on reports by Edward Thiel and J. C. Behrendt, members of the 1957–58 oversnow traverse from IGY Ellsworth Station, and by Father E. A. Bradley, SJ, and F. T. Turcotte, members of the Ellsworth-Byrd traverse, 1958–59.

The oversnow traverse from IGY Ellsworth Station during the Antarctic summer of 1957–58 was confined for the most part to the Filchner Ice Shelf and its fringes. It provided much new information regarding the areal extent of the shelf, its thickness, and the configuration of the underlying bedrock surface, supplementing information gained on exploratory flights over the western portion of the ice shelf and the eastern part of the Ellsworth Highland made during the Ronne Antarctic Research Expedition of 1947–48.

The 67-day, 1250-mile Ellsworth-Byrd Station traverse in the 1958–59 summer season, also carried out by scientific and support personnel from Ellsworth Station, resulted in further knowledge of the ice shelf as well as of ice thickness and sub-ice topography between the edge of the shelf and IGY Byrd Station. Both traverse parties used seismic, gravity, and magnetic techniques

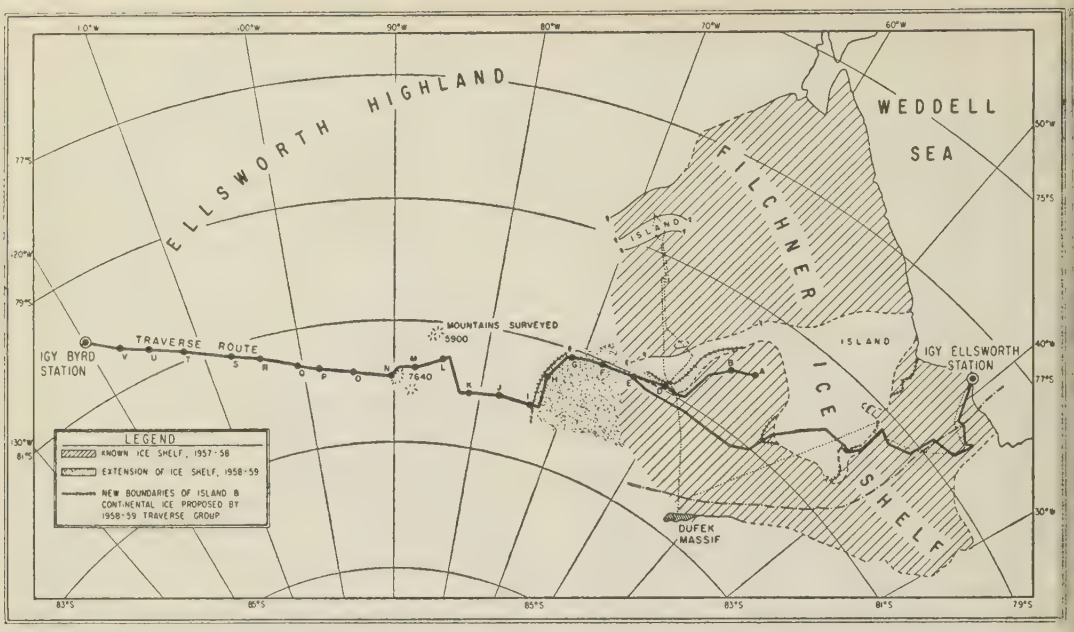

FIG. 5. *US-IGY Traverse Routes from Ellsworth Station. Dotted line represents Filchner Ice Shelf traverse, 1957–58; solid line represents Ellsworth-Byrd traverse, 1958–59. Large, lettered dots are seismic stations along the latter route; dash-dot line is approximate axis of trough beneath the ice shelf.*

primarily for these studies. This report summarizes their findings.

Filchner Ice Shelf

The 1957–58 Ellsworth traverse made three major discoveries concerning the physical geography of the Filchner Ice Shelf: (i) the shelf extends much farther inland and, therefore, has a much greater area than previously supposed; (ii) the shelf is grounded on at least two "islands," one of them of considerable area, and (iii) a deep trough extends inland beneath the shelf from the barrier edge east of Ellsworth Station. (See Figure 5.)

Prior to the IGY, the inner edge of the Filchner Ice Shelf was thought to be about 50–70 miles from the sea in most places, with a maximum of about 150 miles along the western border. The investigations of the 1957–58 Ellsworth Station traverse

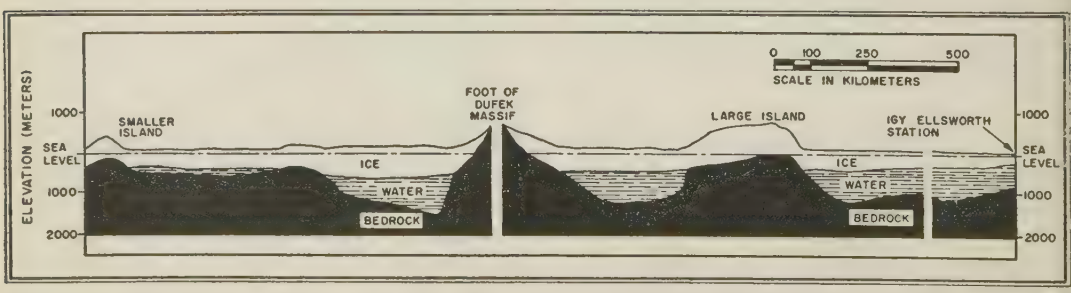

FIG. 6. *Profiles Across Filchner Ice Shelf Along 1957–58 Ellsworth Traverse Route. (Compare with Figure 1.)*

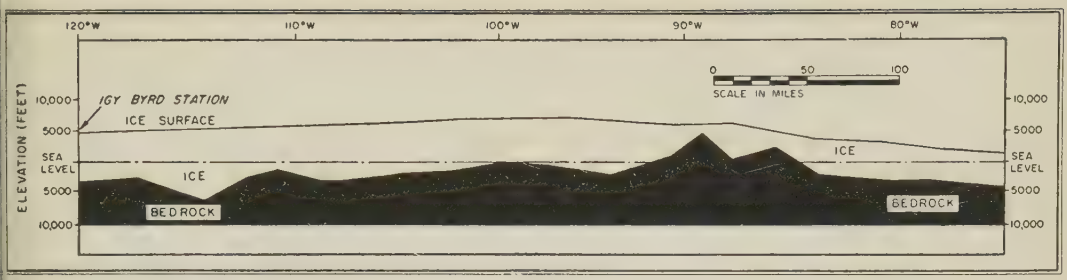

FIG. 7. *Profile from Inland Edge of Filchner Ice Shelf to IGY Byrd Station. (Compare with Figure 1.)*

party, however, showed that the shelf extends inland for distances greater than about 300 miles in most places. In addition, the Ellsworth-Byrd traverse group established the actual contact between the shelf and the mainland along the traverse route an additional 100 miles farther inland. Thus, although its boundaries are still not delineated with certainty in all places, the areal extent of the Filchner Ice Shelf, estimated at approximately 160,000 square miles, is now seen to be comparable to that of the great Ross Ice Shelf (about 210,000 square miles) on the opposite side of Antarctica.

Figure 6, based on seismic investigations conducted along the 1957–58 traverse route, contains profiles of the Filchner Ice Shelf and the islands. Although below sea level almost everywhere they were crossed, these areas are termed islands because they are considerably higher than the surrounding shelf-ice areas and because the overlying ice is actually grounded instead of afloat. In its 1958–59 traverse across the ice shelf, the Ellsworth-Byrd party crossed the large island mapped by the traverse group of the previous year and was able to fill in some additional details of the shelf and the island, as shown in Figure 5.

Figure 5 also indicates the approximate position of the axis of a 3500-foot-deep trough beneath the Filchner Ice Shelf between the large island and the mainland area to the east and southeast of the shelf. It was previously theorized that this trough might represent the Weddell Sea side of a great trans-Antarctic trough thought to extend from the Ross to the Weddell Sea. Whether such a trough actually exists across all of the region between the two seas, however, is still a matter of debate. (See discussions in *Bulletins 19* and *25*, and below.)

Region Between Filchner Ice Shelf and Byrd Station

In the region just beyond the inland edge of the Filchner Ice Shelf, the Ellsworth-Byrd traverse party found a rise in the bedrock surface from about 4000 feet below sea level near the edge of the shelf to about 4000 feet above sea level in a mountainous region in the vicinity of 88°W (see Fig. 7). The mountain area extends at least 70 miles in an east-west direction and appears to be above sea level throughout this region. A number of prominent peaks projecting well above the snow surface were surveyed; the tallest reaches a height of about 7650 feet above sea level, while the surrounding ice-surface elevation ranges from about 4500 to 7000 feet. The group containing this peak was visited and found to be composed of dark gneiss in sharp contact with a light-tan biotite granite.

The region between these mountains and Byrd Station has a bedrock surface virtually everywhere well below sea level. A maximum depth of approximately 6300 feet was measured at 80°35′S, 114°57′W, about 70 miles east of Byrd Station in the region of a broad trough believed by

some investigators to connect the Ross and Bellingshausen Seas (see Bentley and Ostenso, *Bulletin No. 25*). A maximum ice thickness of about 12,000 feet was also measured where this greatest depth to bedrock was found. The topography of the subice surface in this part of the traverse route is generally irregular.

Trans-Antarctic Trough

It was originally hoped that seismic investigations carried out on the Ellsworth-Byrd traverse would furnish evidence either confirming or denying the existence of a trough between the Ross and Weddell Seas. The 70-mile-wide mountainous area in the vicinity of 88°S lends further support to the suggestions of Edward Thiel, N. A. Ostenso, and C. R. Bentley (*Bulletin No. 25*) that a high, mountainous land connection (but mostly buried beneath the ice) may exist between the South Pole area and the mountains of the Palmer Peninsula, breaking the continuity of the hypothetical trough. However, it is not yet known how far south the mountain zone found by the Ellsworth-Byrd traverse party extends. Hence, it is still possible that the trough lies to the south of the traverse route.

An airborne traverse along the 88°W meridian between the Sentinel and Horlick Mountains, to be led by Thiel, is planned for the 1959–60 Antarctic summer season. Seismic, gravity, and magnetic investigations made on this traverse should throw further light on the southward extension of the mountain region discussed above and, therefore, on whether the hypothetical trans-Antarctic trough actually exists.

"PLANET EARTH"

The National Academy of Sciences has prepared a teaching aid known as "Planet Earth," which is of value to students and teachers of the earth sciences. It consists of six large (34" × 48") posters in full color, a 44-page illustrated student brochure, and a Project Leader's Kit containing a variety of supplementary narrative materials. Prices are as follows:

Component	Recommended Classroom Package		Individ. Orders	5–99 to one address	100 or more to one address
Set of 6 Posters	1 set	$9.50	$5.75 per set	$4.75 per set	$4.00 per set
Students' Brochures	30 copies		.50 each	.35 each	.20 each
Project Leaders' Kits	1 kit		.75 each	.60 each	.50 each

Order from National Academy of Sciences, 2101 Constitution Ave., N.W., Washington 25, D. C. Illustrated free circular on request.

Preprinted from *Transactions, American Geophysical Union,* Vol. 40, No. 4, Dec., 1959

Subscription to the Bulletin is $2 for 12 issues beginning with the July 1959 issue (special rates: $1.50 to science teachers and students, and $1 for five or more mailed to a single address). For 36 issues beginning with July 1957, the rate is $6 ($5 and $4 special rates as above). Order from National Academy of Sciences, 2101 Constitution Avenue, Washington 20, D. C.

THE UNIVERSITY OF ILLINOIS AT CHICAGO
3 8198 318 725 874